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Polyethylene Film Box Liners Reduce Weight Loss and Prevent Shriveling of Eastern-Grown Golden Delicious Apples, 1953-54 Season

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Polyethylene Film Box Liners Reduce Weight Loss and Prevent Shriveling of Eastern-Grown Golden Delicious Apples, 1953-54 Season

Recently Gerhardt (1) and Gerhardt and Schomer (2) reported that film box liners were being used to an increasing extent in the Northwest for Golden Delicious apples to prevent shriveling. They recommended polyethylene, Pliofilm, and other films impervious to moisture to reduce moisture loss and thus prevent shriveling of apples and pears. The storage life of pears was also definitely prolonged because of the atmospheres developed within sealed film-lined boxes.

Golden Delicious, an apple with excellent dessert quality, is notably a poor keeper because of its tendency to shrivel and become spongy after 3, 4, or more months in cold storage. The fruit becomes visibly shriveled when it has lost 3 to 5 percent of its weight.

Gerhardt and Schomer found that Golden Delicious apples in cartons and boxes with film bag liners lost 1.9 to 2.9 percent of their weight during 6 months' storage at 31° F. None of these fruit showed any shriveling. Apples in the same types of cartons and boxes with plain and waxed fiberboard liners but no film liners lost 3.6 to 5 percent of their weight and the fruit was shriveled. Gerhardt and Schomer further stated that at the time of removal from storage in April the fruit from the sealed liners was far superior in appearance, condition and dessert quality to the fruit from the standard pack. It was turgid, firm to hand pressure, and fresh in appearance, and had a crisp, juicy texture. The check fruit was shriveled and had a "punky" feel to hand pressure, a tough texture, and a strong aromatic flavor usually associated with advanced ripeness.

Gerhardt and Schomer found polyethylene 150 and Pliofilms 80FML and 80 HP to be satisfactory films when used as sealed liners. However, they recommended that if film liners are sealed, they should be perforated or slit when the fruit is removed from cold storage to avoid possible injury from inadequate gas exchange at higher marketing temperatures.

The purpose of the tests reported here was to determine the effect of moistureproof polyethylene box liners on the shrinkage and storage life of eastern-grown Golden Delicious apples. Comparisons were made of the keeping quality of this variety in sealed and non-sealed polyethylene bag liners and in liners made from overlapping polyethylene sheets. One objective was to determine whether there was any gas-storage benefit (from reduced oxygen and accumulated carbon dioxide) other than maintenance of a high relative humidity to prevent shrinkage.

DESCRIPTION OF TEST

The Golden Delicious apples were harvested from the Plant Industry Station orchard at Beltsville, Md., September 24, 1953, and placed in 31° F. storage in

field boxes. The box-liner test was set up October 15 in wooden northwestern apple boxes. All boxes were lined with regular paperboard box liners and top and bottom pads. Some boxes had polyethylene liners in addition to the regular liners. Golden Delicious apples were packaged in 5 different ways as follows:

1. Regular-pack with paperboard liners (Check).

2. Polyethylene-150 bag liner, sealed, liner perforated on removal from cold storage.

3. Polyethylene-150 bag liner, sealed, liner not perforated on removal from cold storage.

4. Polyethylene-150 bag liner, non-sealed, liner folded over at top.

5. Polyethylene-150 liner, non-sealed, liner made from 2 overlapping sheets.

The liners made of overlapping polyethylene sheets were included because it had been suggested that they might prove more economical than a fabricated bag liner. Dimensions of the polyethylene bag liners were 27 x 19 1/2 x 12 inches (6-inch deep gusset).[1/] Some of these bag liners were perforated on removal from cold storage by making four 2-inch tears in the film near the top of the boxes.

Thirty boxes, or 6 for each of the treatments listed, were jumble-packed with sound Golden Delicious apples of approximately U.S. No. 1 Grade. A heat-sealed closure was used for the sealed polyethylene-liner treatments. No oiled paper was enclosed. Storage was at 31° F. and 85 to 90 percent relative humidity.

Half of the boxes of fruit were examined at 3 months and half at the end of 6 months of storage. Of the 3 boxes under each treatment available for examination one was opened and examined on removal from cold storage. When used, the polyethylene liner was removed and the fruit was held for observation an additional 6 days at 70° F. and 45 to 50 percent relative humidity to simulate a marketing period. The other 2 boxes under each treatment were weighed on removal from cold storage and a sample of gas was withdrawn from each for analysis. These boxes of fruit were not opened until after a 6-day period at 70°.

Firmness was measured with a Magness-Taylor fruit pressure tester (7/16-inch plunger); readings obtained on 3 sides of 20 apples were averaged. Firmness at

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1/ The cooperation of S. J. Perlman of Durapak Manufacturing Co., Baltimore, Md., and A. S. Allen of E. I. du Pont de Nemours and Co., Wilmington, Del., in supplying the polyethylene liners is gratefully acknowledged.

the start of the test averaged 16.2 pounds. Oxygen and carbon dioxide content of the atmosphere in the boxes of fruit were determined with a Hays Orsat analyzer.

RESULTS

Weight Loss and Shriveling - The beneficial effect of moistureproof film liners for Golden Delicious apples was striking after only 3 months' storage at 31° F. The check boxes without film liners had lost 3.5 percent of their weight, and 26.1 percent of the fruit was slightly shriveled. In contrast, fruit in boxes with polyethylene liners had lost 0.1 percent in weight and there was no shriveling (tables 1 and 2).

Table 1.--Weight loss of Golden Delicious apples stored 3 and 6 months at 31° F. in regular- and polyethylene-lined boxes.

Storage period and type of box liner	Weight loss (percent)		
	On removal from cold storage	After 6 days at 70° in unopened boxes	After 6 days at 70° on simulated display 1/
Stored 3 months at 31° F.			
Regular paperboard liners	3.5	5.9	6.3
Polyethylene bag liner, sealed 2/	0.1	1.0	3.5
Polyethylene bag liner, sealed 3/	0.1	1.0	2.8
Polyethylene bag liner, non-sealed	0.1	0.9	3.3
Polyethylene sheets, non-sealed	0.1	1.1	3.4
Stored 6 months at 31° F.			
Regular paperboard liners	6.9	8.7	9.5
Polyethylene bag liner, sealed 2/	0.9	1.5	3.3
Polyethylene bag liner, sealed 3/	0.6	0.9	3.5
Polyethylene bag liner, non-sealed	1.0	1.0	3.8
Polyethylene sheets, non-sealed	1.4	2.4	5.1

1/ Following removal from 31° F. storage these boxes were opened; the film liners were removed, and the fruit in the open boxes was then held 6 days at 70° to simulate marketing.

2/ These liners were perforated on removal from 31° F. storage.

3/ These liners were left sealed on removal from 31° F. storage.

Table 2.--Shriveling of Golden Delicious apples stored 3 and 6 months at 31° F. in regular- and polyethylene-lined boxes.

Storage period and type of box liner	Shriveled apples (percent)		
	On removal from cold storage	After 6 days at 70° in unopened boxes	After 6 days at 70° on simulated display[1]
Stored 3 months at 31° F.			
Regular paperboard liners	26.1	34.9	40.0
Polyethylene bag liner, sealed[2]	0.0	0.0	1.9
Polyethylene bag liner, sealed[3]	0.0	0.0	3.6
Polyethylene bag liner, non-sealed	0.0	0.0	3.0
Polyethylene sheets, non-sealed	0.0	0.0	0.9
Stored 6 months at 31° F.			
Regular paperboard liners	70.7	80.2	82.9
Polyethylene bag liner, sealed[2]	0.0	0.0	2.2
Polyethylene bag liner, sealed[3]	0.0	0.0	4.4
Polyethylene bag liner, non-sealed	0.0	0.5	1.1
Polyethylene sheets, non-sealed	0.0	1.6	5.0

1/ Following removal from 31° F. storage these boxes were opened; the film liners were removed, and the fruit in the open boxes was then held 6 days at 70° to simulate marketing.

2/ These liners were perforated on removal from 31° F. storage.

3/ These liners were left sealed on removal from 31° F. storage.

In April, at the end of 6 months' storage at 31° F., the average weight loss of check boxes was 6.9 percent; percentage of apples shriveled was 70.7 percent. Fruit in polyethylene-lined boxes had lost an average of 0.6 to 1.4 percent in weight and there was still no shriveled fruit.

Non-sealed polyethylene bag liners and liners made from sheets of polyethylene were about as effective as sealed film liners in preventing shriveling. Weight loss from the boxes with polyethylene sheets was slightly higher than from boxes with film bag liners after 6 months, but this was of little or no practical importance.

The apples in the boxes with regular paperboard liners were non-salable at the end of 6 months, whereas the fruit in film-lined boxes was still in good, firm, marketable condition.

Firmness - Apples stored 3 and 6 months at 31° F. in boxes with sealed polyethylene bag liners were firmer than those in non-sealed film-lined boxes. A definite gas-storage effect from the sealed film liners was apparent on removal from 6 months in cold storage, as the apples were 3 to 4 pounds firmer than those in non-sealed film-lined boxes. At the start of the test, the pressure-test reading averaged 16.2 pounds. When the pressure-test readings are expressed as firmness lost since packing, apples in sealed polyethylene lost 2.5 to 2.7 pounds during 6 months' storage (table 3). Those in non-sealed film liners and in check boxes lost an average of 6.4 and 5.1 pounds, respectively, in the same period.

Table 3.--Firmness lost by Golden Delicious apples stored 3 and 6 months at 31° F. in regular- and polyethylene-lined boxes 1/.

Storage period and type of box liner	Firmness lost (pounds) since packing		
	On removal from cold storage	After 6 days at 70° in unopened boxes	After 6 days at 70° on simulated display
Stored 3 months at 31° F.			
Regular paperboard liners	4.8	5.6	5.7
Polyethylene bag liner, sealed 2/	2.6	4.9	4.0
Polyethylene bag liner, sealed 3/	2.9	3.4	---
Polyethylene bag liner, non-sealed	5.0	6.5	6.4
Polyethylene sheets, non-sealed	5.1	6.5	6.4
Stored 6 months at 31° F.			
Regular paperboard liners	5.1	6.3	5.1
Polyethylene bag liner, sealed 2/	2.7	4.6	3.4
Polyethylene bag liner, sealed 3/	2.5	3.6	3.2
Polyethylene bag liner, non-sealed	6.4	7.2	7.0
Polyethylene sheets, non-sealed	6.4	6.9	6.8

1/ Apples in boxes with regular liners became spongy so that the pressure-test reading was not a good measure of firmness after prolonged storage. At start of test the pressure-test reading was 16.2 pounds.

2/ These liners were perforated on removal from 31° F. storage.

3/ These liners were left sealed on removal from 31° F. storage.

After a 6-day holding period at 70° F. following 6 months at 31°, apples in sealed liners were still 2 to 3 pounds firmer than those in non-sealed film-lined boxes.

The check fruit became spongy as it lost weight and for this reason the pressure tester did not give a good relative measure of its firmness. As a consequence, the pressure tester showed check fruit to be firmer than that in non-sealed polyethylene-lined boxes. Actually, the check fruit was very inferior in condition because of weight loss and shriveling.

Ground Color - The ground color as measured on a standard-color chart for apples and pears was determined on 20 fruits from each of 4 treatments. This chart employs a 1- to-4 rating system for shades of green to yellow indicative of degree of ripeness. The ground color rating at harvest was 2.3. The ground colors, after 6 months' storage at 31° F. followed by a 6-day holding period at 70°, are shown in table 4. The fruit with the lowest ground color ratings (greenest) was in boxes with a polyethylene bag type of liner. This fruit was significantly greener than fruit in boxes lined with polyethylene sheets. The ripest fruit, according to ground color ratings, was in check boxes without film liners and in boxes lined with non-sealed polyethylene sheets. The fruit in these last boxes had a good yellow color and was firm and unshriveled.

Table 4.--Ground color and storage scald of Golden Delicious apples after storage in regular- and polyethylene-lined boxes.

Storage period and type of box liner	Ground color (1-4 rating)1/	Storage scald (percent)
None (at harvest)	2.3	---
Stored 6 months at 31° F. + 6 days at 70°.		
Regular paperboard liners	3.5	62/
Polyethylene bag liner, sealed	2.8	0
Polyethylene bag liner, non-sealed	2.9	3
Polyethylene sheets, non-sealed	3.6	82/
L.S.D. for ground color at 1 percent level =	0.4	

1/ Standard ground color chart for apples and pears issued in 1929 by the U. S. Department of Agriculture, Bureau of Plant Industry. The values shown are the average color on 2 sides of 20 apples.

2/ These lots of apples with slightly more scald appeared riper (more yellow color) than lots in boxes with polyethylene bag liners.

Storage Scald - There was no storage scald in any of the boxes after 3 months at 31° F. plus 6 days at 70°. A slight amount of scald was found on fruit in check boxes and in non-sealed polyethylene-lined boxes after 6 months at 31° plus 6 days at 70°. Scald appeared to be highest on the lots which were ripest, as shown in table 4.

Ripeness and Flavor - A panel of 12 judges compared the ripeness and flavor of fruit from 3 of the treatments after 6 months in storage. Their average ratings are summarized in table 5. The rate of ripening of apples in sealed polyethylene bag liners was retarded over that of those in non-sealed film liners and of the check fruit. This was apparent to the judges as a slight color difference (fruit in sealed liners not as yellow) and as a texture difference. The effect of gas storage in sealed film liners, as evidenced by a delay in ripening, showed up both on removal from cold storage and after a 6-day holding period at 70° F.

Table 5.--Ripeness and flavor ratings of Golden Delicious apples stored in regular- and polyethylene-lined boxes. 1/

Storage period and type of box liner	Ripeness (10-1 rating)	Flavor (10-1 rating)
Stored 6 months at 31° F.		
Regular paperboard liners	5.7	4.3
Polyethylene bag liner, sealed	7.5	5.8
Polyethylene bag liner, non-sealed	4.5	5.9
Stored 6 months at 31° + 6 days at 70° F. 2/		
Regular paperboard liners	5.6	5.8
Polyethylene bag liner, sealed	7.4	6.0
Polyethylene bag liner, non-sealed	5.0	6.0

1/ Values shown are averages of the ratings by 12 judges. Ripeness ratings were firm ripe 10-8, ripe 7-4, overripe 3-1. Flavor ratings were apple aroma strong 10-8, mild 7-4, off-flavor 3-1.

2/ These boxes were not opened until the end of the 6-day period.

After the apples were held 6 months in cold storage the flavor of those in film liners was slightly preferred to that of regular-packed fruit. After the 6-day holding period at 70° F., flavor differences between check boxes and

film-packaged fruit were negligible, although the appearance of the fruit from film-lined boxes was much superior. It should be pointed out that the flavor ratings shown are averages; several judges, including the author, described the fruit from sealed film-lined boxes as being slightly fermented, wine flavored, or having an abnormal flavor, while others described it as spicy or tart. Check fruit was given almost the same numerical flavor rating as that of film-packaged fruit but for a different reason, advanced ripeness.

Soluble Solids - A hand refractometer was used to determine the soluble-solids content of fruit given 3 of the treatments. The percentage of soluble solids in apples gives an approximate value of the sugar content. No differences of practical importance were found between check fruit and fruit in polyethylene-lined boxes after 3 and 6 months in storage, as shown in table 6. After 6 months at 31° F. the average soluble solids ranged from 14.7 to 15.8 percent.

Table 6.--Soluble solids in Golden Delicious apples stored in regular- and polyethylene-lined boxes.

Type of box liner	Solids Solids (percent)1/		
	After 3 months : 31° F. + 6 days : 70°	After 6 months : 31° F.	After 6 months : 31° F. + 6 days : 70°
Regular paperboard liners	14.8	15.8	14.7
Polyethylene bag liner, sealed	16.5	15.0	15.5
Polyethylene sheets, non-sealed	15.1	14.7	14.3
L.S.D. for 1 percent level =	1.6	1.6	1.0

1/ Measured with Bausch and Lomb juice refractometer, 0 to 25 percent scale. Boxes were not opened until date of examination.

Decay - The decay shown in table 7 was mainly blue and gray mold rots. Decay at the end of 3 months' storage was highest in the regular, or check, boxes. Most of this developed at bruised areas or in mechanical skin breaks such as those caused by stem punctures. It should be pointed out that the decay data are based on only 1 or 2 boxes under each treatment.

Table 7.--Decay of Golden Delicious apples stored 3 and 6 months at 31° F. in regular- and polyethylene-lined boxes.

Storage period and type of box liner	Decay (percent)		
	On removal from cold storage	After 6 days at 70° in unopened boxes	After 6 days at 70° on simulated display
Stored 3 months at 31° F.			
Regular paperboard liners	3.4	6.4	10.1
Polyethylene bag liner, sealed 1/	1.6	1.2	3.9
Polyethylene bag liner, sealed 2/	0.0	0.8	1.5
Polyethylene bag liner, non-sealed	0.0	2.1	0.8
Polyethylene sheets, non-sealed	1.5	1.6	3.0
Stored 6 months at 31° F.			
Regular paperboard liners	16.3	10.4	22.0
Polyethylene bag liner, sealed 1/	2.5	2.0	3.3
Polyethylene bag liner, sealed 2/	1.6	2.8	2.3
Polyethylene bag liner, non-sealed	2.5	2.2	2.5
Polyethylene sheets, non-sealed	4.7	13.5	7.0

1/ These liners were perforated on removal from 31° F.

2/ These liners were left sealed on removal from 31° F.

After 6 months' storage decay was again highest in the check boxes without a film liner. However, when the various boxes of apples were held unopened an additonal 6 days at 70° F., decay was also high in boxes lined with polyethylene sheets. The high amount of decay in this lot (13.5 percent) was caused by gray mold, which "nested". Decay was lowest, 1 to 3 percent, in boxes with the polyethylene bag type of liner.1/ It appears that decay was reduced by a build-up of carbon dioxide (3 to 10 percent) in the polyethylene bag type of box liner even when the liners were unsealed and merely folded over at the top. This is discussed later on page 11.

Some surface mold developed on the apples in film-lined boxes as a result of the high humidity. It was most evident on the stem and in the stem scar. As most of this surface mold disappeared a short time after the boxes were opened, it was not considered a serious defect. Smith (3) also noted the prevalence of surface

1/ Two boxes with non-sealed film bag liners held until June (8 months) had an average of 8.5 percent decayed fruit, mostly gray mold rot. The sound fruit in these boxes was still firm with no shriveling, but it had a somewhat mealy texture.

mold on stems of Golden Delicious apples when polyethylene was used as individual wraps and as bag liners.

Oxygen and Carbon Dioxide in Box Atmosphere - Data on the oxygen and carbon dioxide contents of the atmosphere within the various box liners, as determined by Orsat gas analyses, are presented in table 8. As expected, the oxygen content in check boxes, with regular liners, was similar to that in normal air, 21 percent, and the carbon dioxide was less than 0.5 percent after 6 months in cold storage. Oxygen in boxes with sealed polyethylene liners was reduced to an average of 2.4 to 2.8 percent after 6 months in cold storage; one box had only 0.9 percent oxygen. The carbon dioxide in these sealed boxes averaged 5.5 to 5.9 percent.

Table 8.--Oxygen and carbon dioxide contents of the atmosphere in regular- and polyethylene-lined boxes of Golden Delicious apples stored 3 and 6 months at 31° F.

Storage period and type of box liner	On removal from cold storage		After 6 days at 70° in unopened boxes	
	Oxygen (percent)	Carbon dioxide (percent)	Oxygen (percent)	Carbon dioxide (percent)
Stored 3 months at 31° F.				
Regular paperboard liners	21.0	0.2	21.0	0.2
Polyethylene bag liner, sealed 1/	5.5	5.2	19.1	1.9
Polyethylene bag liner, sealed 2/	7.0	5.8	0.6	12.9
Polyethylene bag liner, non-sealed	20.0	0.8	11.3	7.2
Polyethylene sheets, non-sealed	21.0	0.5	18.5	2.0
Stored 6 months at 31° F.				
Regular paperboard liners	19.9	0.1	20.6	0.4
Polyethylene bag liner, sealed 1/	2.8	5.9	19.0	1.5
Polyethylene bag liner, sealed 2/	2.4	5.5	1.5	10.1
Polyethylene bag liner, non-sealed	17.6	2.9	9.3	9.8
Polyethylene sheets, non-sealed	20.2	0.5	17.7	2.9

1/ These liners were perforated on removal from 31° F. storage.
2/ These liners were left sealed on removal from 31° F. storage.

When sealed film-lined boxes of apples were held 6 days at 70° F. following 6 months' storage at 31°, oxygen was depleted to an average of 1.5 percent. Carbon

dioxide averaged 10.1 percent in these boxes. Published information on gas storage of apples indicate that abnormal atmosphere such as this can be considered dangerous. Off-flavors resulting from suboxidation could be expected. Actually, as already discussed, some of the taste panel described the flavor of the apples from sealed film-lined boxes as being slightly fermented or wine flavored, while others liked the flavor and described it as being tart or spicy.

Perforating sealed film liners at the time of removal from cold storage for marketing, as previously suggested by Gerhardt and Schomer (2), appears to be a desirable practice. In this test the liners were perforated by making four 2-inch tears in the film near the top of the boxes. When the liners were perforated in this manner, the oxygen and carbon dioxide contents at the end of the 6-day holding period at 70° F. averaged 19.0 and 1.5 percent, respectively.

Oxygen was not depleted and carbon dioxide did not accumulate to dangerous levels when non-sealed polyethylene bag liners were used in the cold storage of Golden Delicious apples (table 8). When apples in such liners were held 6 days at 70° F. following 6 months at 31°, the oxygen and carbon dioxide content of the atmosphere both were between 9 and 10 percent. This indicates that even in these non-sealed film bag liners the movement of respiratory gases was restricted at ordinary room temperatures. A slight gas-storage effect on the rate of ripening in these non-sealed polyethylene bag liners has already been mentioned.

Boxes lined with polyethylene sheets had oxygen and carbon dioxide contents which were fairly normal for cold storage; that is, similar to check boxes with regular liners. When the boxes were held at 70° F. only slight depletion of oxygen or accumulation of carbon dioxide occurred.

Analyses of the atmosphere in the various boxes after 3 months at 31° F. were approximately like those found after 6 months. The oxygen and carbon dioxide in sealed polyethylene-lined boxes after 3 months at 31° plus 6 days at 70°, averaged 0.6 and 12.9 percent, respectively.

Fruit Internal Atmosphere - After 6 months at 31° F. followed by 6 days at 70°, the internal atmosphere from 4 apples from each of the 5 packaging treatments was extracted under vacuum by displacement into a saline solution. The gas was extracted during a 10-minute period under 25 to 26 inches of vacuum. The values for oxygen and carbon dioxide were obtained by analyzing duplicate 50-ml. aliquots of the extracted atmosphere. The gas samples were collected within 5 to 10 minutes after the boxes were opened.

Gas extracted from check fruit contained 19.6 percent oxygen and 4.2 percent carbon dioxide (table 9). Quite abnormal atmospheres of 4.1 and 18.0 percent oxygen and carbon dioxide, respectively, were found within fruit stored in sealed film liners not perforated on transfer to room temperature. These concentrations of gases are further evidence of the desirability of perforating sealed film liners on removal from cold storage. The internal oxygen contents of apples

in boxes lined with non-sealed polyethylene sheets or with sealed polyethylene bags perforated on removal from cold storage was 16.8 and 17.7 percent, respectively, which were only slightly different from fruit in check boxes.

Table 9.--Composition of internal atmosphere extracted from Golden Delicious apples in regular or polyethylene-lined boxes stored 6 months at 31° F. followed by 6 days at 70°.[1/]

Type of box liner	Gas volume (ml./kg. fruit)	Oxygen (percent)	Carbon dioxide (percent)
Regular paperboard liners	342	19.6	4.2
Polyethylene bag liner, sealed[2/]	425	17.7	5.2
Polyethylene bag liner, sealed[3/]	358	4.1	18.0
Polyethylene bag liner, non-sealed	369	10.0	15.8
Polyethylene sheets, non-sealed	353	16.8	7.6

1/ Values are based on gas extracted from 4 apples in 10 minutes under 25 to 26 inches of vacuum.
2/ These liners were perforated on removal from 31° F. storage.
3/ These liners were left sealed on removal from 31° F. storage.

SUMMARY AND CONCLUSIONS

The conclusions of Gerhardt and Schomer (2) as to the benefits of using moistureproof film box liners for Golden Delicious apples grown in the Northwest are substantiated in these tests with eastern-grown Golden Delicious. This variety, which is rated a poor keeper because of excessive shriveling during prolonged cold storage, was still in good condition with no shriveling and only about 1 percent weight loss after 6 months' storage at 31° F. in polyethylene-lined boxes. Check boxes with regular paperboard liners were unsalable then because 70 percent of the apples were shriveled and weight loss was about 7 percent.

The benefit of moistureproof film box liners in preventing weight loss and shriveling of the fruit was apparent after only 3 months at 31° F. It is believed that the added cost of using film liners would be justified for this variety because of improved keeping quality even for medium-length storage of 3 to 4 months.

After a holding period of 6 days at 70° F. on simulated retail display, following removal from cold storage, Golden Delicious apples from film-lined boxes were still in much better condition than those from regular boxes.

When sealed polyethylene box liners were used, a definite gas-storage effect was apparent after 6 months. Apples in such sealed film-lined boxes were 3 to 4 pounds firmer than those in non-sealed film-lined boxes. Their rate of ripening, based on ground color changes and on ripeness ratings by a taste panel was slower. The oxygen content of the atmosphere in sealed boxes was reduced after 6 months at 31° F. to 2 to 3 percent and carbon dioxide accumulated to 5 to 6 percent as a result of respiration of the fruit. When the apples were held an additional period at room temperature in the sealed boxes after removal from cold storage, the oxygen content was further reduced and carbon dioxide continued to accumulate.

A harmful atmosphere did not develop in boxes with non-sealed bag type liners while in cold storage. However, such liners did restrict respiratory-gas exchange considerably at 70° F. They appear to be safe for use as the oxygen content was not reduced below 9 percent even when held as long as 6 days at 70° following cold storage.

Non-sealed, rather than sealed, polyethylene or similar types of film box liners are recommended for Golden Delicious apples for the following reasons:

1. They are as satisfactory as sealed liners for preventing shriveling and weight loss.

2. They largely eliminate the possibility of fruit injury from too low oxygen and too high carbon dioxide. Oxygen was depleted to less than 1 percent in one box with a sealed film liner in 31° F. storage. There were some complaints of off-odors and off-flavors in the fruit in sealed boxes, especially, when the film liners were not perforated on removal from cold storage. Although there was some beneficial gas-storage effect on the fruit in sealed film-lined boxes, it is believed that possible dangers outweigh the advantages.

3. Using non-sealed or perforated film liners eliminates the need to perforate the liner for ventilation when boxes are removed from cold storage for marketing.

Film box liners made from 2 overlapping polyethylene sheets were also satisfactory for maintaining good quality by reducing weight loss and eliminating shriveling.

Film box liners for Golden Delicious apples are suggested only for that portion of the crop intended for medium to late storage. Only sound fruit free from orchard infection should be used, because the high humidity which develops within moistureproof liners makes conditions ideal for decay development.

Further tests with film box liners are contemplated for Golden Delicious and other varieties of apples. Perhaps a method of using a sealed or partially sealed film liner can be developed whereby the beneficial effect of modified atmospheres which develop can be used to advantage.

The main advantage of non-sealed film box liners over regular paperboard liners for Golden Delicious apples is prevention of weight loss and shriveling. Film liners might also have value as a substitute for regular liners which are used to prevent abrasion in wooden boxes.

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